REPORT

Tank 1010 Area Remedial Approach Report Institute Facility Institute, West Virginia

Prepared for

Union Carbide Corporation

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ch2m

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Acronyms and Abbreviations

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
AS	air sparge
AS/SVE	air sparge/soil vapor extraction
AST	aboveground storage tank
BCS	Bayer CropScience
bgs	below ground surface
COC	constituent of concern
CSM	conceptual site model
Dow	The Dow Chemical Company
DPT	direct-push technology
DTI	Deep Earth Technologies, Inc.
facility	UCC Institute Facility, Institute, West Virginia
HI	hazard index
HPH	High-Purity Hydrocarbon
ISCO	in situ chemical oxidation
MG	million gallon(s)
MMP	Materials Management Plan
MNA	monitored natural attenuation
NAPL	nonaqueous phase liquid
O&M	operations and maintenance
RAO	remedial action objective
RAR	Remedial Approach Report
RCRA	Resource Conservation and Recovery Act
SEE	steam-enhanced extraction
SVE	soil vapor extraction
TCH	thermal conductive heating
TEVET	thermally enhanced vapor extraction technology
TTZ	target treatment zone
UCC	Union Carbide Corporation
USEPA	U.S. Environmental Protection Agency
VI	vapor intrusion
VOC	volatile organic compound

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WV 25	West Virginia Route 25
WVDEP	West Virginia Department of Environmental Protection

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SECTION 1

Introduction

This Remedial Approach Report (RAR) addresses the Tank 1010 Remediation Area, also known as the "Tank 1010 Area," at the Union Carbide Corporation (UCC) Institute Facility (hereafter referred to as the "facility") in Institute, West Virginia. **Figure 1-1** presents an overview of the facility and the general location of the Tank 1010 Area. The work is part of the Resource Conservation and Recovery Act (RCRA) Corrective Action process under authority of the U.S. Environmental Protection Agency (USEPA).

The facility began operations in 1943 during World War II as a synthetic rubber production plant owned by the federal government. UCC purchased and operated the facility from 1947 to 1986. In 1986, the facility was purchased by Rhone-Poulenc, which became Adventis CropScience in January 2000 and subsequently Bayer CropScience (BCS) in 2002. The facility was purchased by UCC in March 2015. The main chemical plant historically produced various hydrocarbon and agricultural products.

In June 2014, UCC, USEPA, and the West Virginia Department of Environmental Protection (WVDEP) met to discuss the overall strategy for the Tank 1010 Area and agreed on the remedy approach documented in this report.

1.1 Purpose

The purpose of this report is to present:

- The conceptual site model (CSM) for the Tank 1010 Area;
- The Tank 1010 Area remedial action objectives (RAOs);
- The Tank 1010 Area target treatment zone (TTZ) (i.e., area of the site where remediation will be applied to achieve the RAOs); and
- The remedies evaluated, the selected remedy, and its implementation for the Tank 1010 Area.

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SECTION 2

Conceptual Site Model

2.1 Site Background

Tank 1010 is a 1.47-million-gallon (MG) aboveground storage tank (AST) placed into service in 1943 as a benzene storage tank. Benzene was used as a raw material for two styrene production units. Benzene was received by railcar on either side of a piping trench located north of Tank 1010 and transferred to Tank 1010 by connecting a flexible hose at the base of the railcar to a pipe connection within the piping trench. Benzene was then transferred from Tank 1010 to the styrene production units via piping extending through a tunnel beneath the tracks on the northwest side of the tank secondary containment area. Tank 1010 remained in benzene service until 1981. Since 1981, the tank has been in service for the glycol process unit and currently is used for the storage of anti-freeze-grade ethylene glycol.

The Tank 1010 Area is presented on **Figure 2-1**. As shown on this figure, a section of the inactive railroad sidings and pipe trench was demolished in October 2014 in preparation for site remediation activities.

2.2 Site Setting

The facility is located on an elevated alluvial floodplain (approximately 1,200 to 3,500 feet wide) along the northern bank of the Kanawha River. The facility topography is relatively flat in part due to the location and in part because of onsite filling and grading activities conducted in the past to support industrial operations adjacent to the Kanawha River. North of West Virginia Route 25 (WV 25), which parallels the northern facility boundary, the topography becomes comparably steeper as it transitions from the floodplain to hilly slopes. In general, the southern facility boundary that abuts the Kanawha River consists of steep slopes covered by riprap.

2.3 Geology and Hydrology

Subsurface conditions at the facility consist of a sequence of alluvial deposits associated with the ancestral Kanawha River. These alluvial deposits are approximately 55 to 60 feet thick and consist primarily of interbedded gravel, sand, silt, and clay deposits. The thickness of the alluvium thins dramatically along the inland side of the facility as bedrock rises up to the hilly area. Site development has resulted in the addition of manmade and natural fill materials that range up to approximately 10 feet in thickness. An important subsurface feature is the presence of relatively thick strata of clay and silt along the riverbank.

The geology of the Tank 1010 Area consists of about 30 to 35 feet of silt and clay (fine-grained unit) underlain by approximately 15 to 20 feet of sand and gravelly sand (coarse-grained unit). The coarse-grained unit overlies bedrock. Subtle gradational changes occur within the fine-grained unit (e.g., sandy clay grading to clayey sand and back to sandy clay). This unit becomes saturated approximately 15 feet below ground surface. Sandy seams and/or lenses occur at varying depths within the fine-grained unit; however, they do not appear to be laterally continuous. These seams and lenses are also generally saturated, but they do not indicate the presence of a perched aquifer.

The coarse-grained unit constitutes the aquifer beneath the Tank 1010 Area. Based on potentiometric surface measurements relative to the depth of the interface between the fine and coarse grained units, the aquifer appears to be semi-confined.

The difference in groundwater elevation as measured in monitoring wells screened within the fine-grained unit and coarse-grained unit suggests a downward vertical gradient. It is also suggested by the nature and extent of contamination (see Section 2.4). Groundwater within the aquifer in this area generally flows to the southeast toward the Kanawha River. A cross-section location map is included as **Figure 2-2** and geologic cross-sections of the Tank 1010 are included as **Figure 2-3** and **Figure 2-4**.

2.4 Nature and Extent of Contamination

Investigation activities at the Tank 1010 Area have been conducted between 2009 and 2014 to characterize potential soil, groundwater, and pore water impacts, and the associated source areas. Investigation activities began in 2009 as an effort to identify the source of elevated volatile organic compound (VOC) concentrations, specifically benzene, detected in the aquifer at soil boring INS-0005. This boring was part of sampling associated with the High-Purity Hydrocarbon (HPH) Area, located immediately west of the Tank 1010 Area. Investigation activities completed at the Tank 1010 Area in 2010 and 2011 identified source concentrations of benzene in soil and groundwater north of Tank 1010 between the secondary containment area and the former piping trench historically used to transfer benzene from rail cars to the tank (**Figure 2-1**).

2.4.1 Surface Water Screening Levels

UCC has developed surface water screening levels to be protective of potential Kanawha River exposure pathways for human and ecological receptors. The processes, analytical data, and calculations used to develop these criteria are presented in the *Groundwater to Surface Water Screening Levels and Risk Evaluation* (CH2M HILL [CH2M] 2012). The constituents of concern (COCs) present at the Tank 1010 Area and their associated surface water screening criteria are as follows (CH2M 2012):

- Benzene: 130 micrograms per liter (µg/L)
- Ethylbenzene: 7.3 µg/L
- Toluene: 9.8 µg/L
- Xylenes: 67 µg/L
- Naphthalene: 193 µg/L
- Carbon Disulfide: 105 µg/L
- Styrene: 72 µg/L

COCs detected in groundwater and pore water are compared to these screening levels.

2.4.2 Impacts to Soil

Investigation data indicate that primary COCs detected in soil within the Tank 1010 Area are the VOCs benzene, toluene, ethylbenzene, xylenes, and naphthalene. Of these, benzene is the COC detected most frequently and at the highest concentration in soil. The highest benzene concentration detected in soil was 17.5 million micrograms per kilogram (µg/kg). The highest benzene concentrations in soil have been detected north of Tank 1010 between the former pipe trench and secondary containment dike wall at depths ranging from 10 to 20 feet below ground surface (bgs) within the fine-grained unit.

A second, smaller VOC-impacted area was identified south of Tank 1009 near borings INS-0049 and INS-0040; however, the maximum benzene concentration observed in this area (101,000 µg/kg) was orders of magnitude lower than the maximum detection within the former piping trench area. The benzene detection south of Tank 1009 was observed in the fine-grained unit between approximately 9.5 and 10 feet bgs. **Figure 2-5** presents the soil boring locations and an isocontour for benzene concentrations in soil in the Tank 1010 Area. Soil analytical results from the investigation at the Tank 1010 Area are included in the report, *Tank 1010 Source Area Investigation* (CH2M 2011).

2.4.3 Impacts to Groundwater

Benzene, toluene, ethylbenzene, xylenes, and naphthalene are the COCs detected in both shallow groundwater within the fine-grained unit and the underlying aquifer at the Tank 1010 Area above their respective screening levels. Styrene and carbon disulfide have also been detected above their respective screening levels; however, these COCs are not detected throughout the Tank 1010 Area. The highest benzene concentration detected in groundwater (861,000 µg/L) was observed in a grab sample collected hydraulically downgradient of benzene-impacted soils associated with the former piping trench. **Figure 2-6** depicts the concentration of benzene in the aquifer as well as the pore water results from sampling completed in 2012. Results from the groundwater investigation in the Tank 1010 Area are included in the report, *HPH and Tank 1010 Pore Water Characterization Report* (CH2M 2013).

2.4.4 Impacts to Kanawha River Pore Water

Seventeen pore water samples were collected in 2012 and analyzed for the site-specific COCs detected in soil and groundwater within the Tank 1010 Area. The samples were collected to assess potential discharges of groundwater COCs to the Kanawha River hydraulically downgradient of the Tank 1010 Area. Benzene and ethylbenzene were not detected in the pore water samples. Toluene was detected at 14 sample locations, xylenes were detected at 11 sample locations, and naphthalene was detected in five sample locations. However, the toluene, xylene, and naphthalene concentrations were below the established surface water screening levels for the Kanawha River. Figures illustrating the 2012 groundwater plumes for benzene, toluene, ethylbenzene, and xylenes, including the pore water results from samples collected downgradient of the Tank 1010 Area, are presented in the report, *HPH and Tank 1010 Pore Water Characterization Report* (CH2M 2013).

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Remedial Action Objectives

3.1 Remedial Action Objectives

RAOs were developed for the facility and established in accordance with the RCRA framework to be protective of human health and the environment. Based on the facility RAOs and site-specific conditions, the following RAOs have been retained for the Tank 1010 Area:

1. Reduce source area VOC mass (primarily benzene) in source area north of Tank 1010;
2. Improve groundwater quality consistent with the groundwater performance monitoring plan;
3. Address vapor intrusion (VI) risks with active soil/groundwater remediation or engineering controls, as necessary; and
4. Prevent unacceptable direct contact with soil and groundwater through engineering and/or institutional controls (e.g., soil management plan).

The first and second RAOs can be satisfied through active remediation in that portion of the Tank 1010 area where the highest COC concentrations are accessible to treatment. Active remediation will reduce VOC mass in soil where it is appears to be acting as a source to groundwater. Source area mass reduction will ultimately improve groundwater quality within both the fine-grained unit and underlying aquifer.

One occupied building (Building 15) is located southwest of the Tank 1010 Area. VI risks were evaluated for Building 15, and the associated carcinogenic risk estimates were within USEPA's risk management range. Noncancer hazard indices (HIs) were below the threshold of 1.0 (CH2M 2014). No other occupied buildings are located within the Tank 1010 Area; however, to satisfy the third RAO, vapor control systems or other VI mitigation measures will be used in any future constructed buildings to prevent unacceptable VI risks.

To address the fourth RAO, institutional controls, including development of a Materials Management Plan (MMP), will be implemented on a sitewide basis to prevent direct exposure of human receptors to soil and groundwater.

3.2 Target Treatment Zone

The area in which active remediation will be conducted to satisfy the first and second RAOs will be hereafter referred to as the target treatment zone (TTZ). Active remediation within the TTZ is expected to result in overall improvement in groundwater quality and maintain pore water concentrations that are protective of the river ecology.

3.2.1 Primary Source Area

As stated in Section 2.4.2 and shown in **Figure 2-5**, the highest benzene concentrations in soil have been detected north of Tank 1010 between the former pipe trench and secondary containment dike wall. However, not all of the benzene detected in soil in this area is accessible to active remediation. Benzene-impacted soils are inaccessible for active remediation (e.g., fracturing, excavation, etc.) to the north due to the active Norfolk Southern Railway lines, to the west by a large utility corridor (including a tunnel), and to the south by the Tank 1010 secondary containment structure. Remediation activities are not allowed by Norfolk Southern within 25 feet of the active rail lines.

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The TTZ is defined as the area where benzene concentrations in accessible soils exceed concentrations that are likely to leach to groundwater at levels that result in concentrations that continue to exceed site-specific cleanup criteria. Benzene concentrations exceeding 100,000 µg/kg were targeted for active remediation. The resulting TTZ is approximately 2,600 square feet (130 feet by 20 feet) in size. **Figure 3-1** illustrates the size of the TTZ relative to the benzene soil isocontour lines.

Vertically, the TTZ encompasses the fine-grained unit that overlies the sand aquifer where benzene concentrations exceed 100,000 µg/kg. Soil impacts within the upper 5 feet of the TTZ are negligible, and the highest benzene concentrations within the fine-grained unit have generally been detected between approximately 5 and 20 feet bgs. Therefore, the vertical extent of the TTZ ranges from 5 to 20 feet bgs.

Active remediation within the TTZ will result in the treatment of approximately 60 percent of the estimated benzene mass in the source area north of Tank 1010.

3.2.2 Secondary Source Area

A separate possible source area was identified south of Tank 1009, referred to as the "secondary source area." The highest benzene concentrations observed at depths ranging between approximately 9.5 and 10 feet bgs in the secondary source area and were several orders of magnitude lower than the maximum detection within the former piping trench area. The secondary source area is not accessible to active remediation because of the number of underground utilities that run through this area and the presence of Tank 1009 and its supporting infrastructure. Therefore, active remediation of the secondary source area was not considered further at this time.

SECTION 4

Remedy Evaluation Selection

4.1 Remedial Technology Screening

Based on the RAOs presented in Section 3.1, remedial technologies were identified and screened for the Tank 1010 Area. The remedial technology screening for the Tank 1010 Area consisted of a two-step screening process. The first step screened out technologies unable to be implemented within the TTZ or that would have limited effectiveness based on site geologic conditions and COC nature and extent. The following technologies were retained for additional evaluation:

- Administrative and institutional controls
- Monitored natural attenuation (MNA)
- In-situ chemical oxidation (ISCO)
- Air sparge and soil vapor extraction (AS/SVE) with soil fracturing
- Thermal conductive heating (TCH)
- Steam enhanced extraction (SEE)
- Excavation and offsite disposal
- Excavation and onsite treatment and reuse

Vendors were contacted to further assess implementability, effectiveness, and costs, and to assist in the development of a conceptual approach. Additionally, other aspects evaluated to further screen the technologies included security and logistics (the TTZ is located outside the facility fence along active railroad lines), protectiveness of adjacent structures, and permitting requirements. Five remedial technologies were retained following the second screening step:

- Administrative and institutional controls
- MNA
- ISCO
- Excavation and offsite disposal
- Excavation and onsite treatment and reuse

Table 4-1 presents a summary of the remedial technologies considered during the first and second screening steps and those retained as remedial alternatives for further detailed evaluation. Section 4.2 presents a summary of the remedial alternatives developed for the Tank 1010 TTZ.

4.2 Remedial Alternatives

This section presents remedial alternatives developed based on the remedial technology screening. Although not specifically referenced, administrative and institutional controls and MNA are a component of each alternative. Administrative and institutional controls are part of each alternative in order to meet the RAOs, specifically to prevent unacceptable direct contact with soil and groundwater due to the inaccessibility of impacted soils in some areas and protect against potential future VI risks. MNA is a component of each of the remedies because some source area soils are inaccessible and natural attenuation has been observed to be occurring in groundwater and is expected to continue.

All of the alternatives also include demolition of the inactive railroad sidings and pipe trench north of Tank 1010.

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4.2.1 Alternative 1 – Excavation, Ex-Situ Onsite Treatment, and Offsite Disposal or Onsite Reuse

This alternative consists of excavating soil to 20 feet bgs using either traditional earthmoving equipment or large-diameter augers. Based on the proximity to adjoining structures and geotechnical soil properties collected, shoring would be required to stabilize the excavation perimeter. Because the fine-grained soils become saturated at 20 feet bgs, dewatering may be required under this alternative.

The alternative assumes the upper 5 feet of soil can be reused as excavation backfill. The remainder of the excavation would be backfilled using clean borrow material. Soil excavated from 5 to 20 feet bgs would be stockpiled separately for onsite treatment. The soil would be placed in treatment cells and treated using thermally enhanced vapor extraction technology (TEVET). The treated soil would either be transported offsite for disposal at a Subtitle D landfill approved by The Dow Chemical Company (Dow) or reused within the facility. The decision to transport and dispose offsite versus onsite reuse would be dependent on the concentrations to which the treatment technology could reduce COC concentrations in the soil and associated risks.

4.2.2 Alternative 2 – Excavation, Offsite Treatment, and Offsite Disposal

Alternative 2 is similar to Alternative 1 with the difference that soil excavated from 5 to 20 feet bgs would be transported offsite to a Dow-approved facility for treatment and disposal.

4.2.3 Alternative 3 –In Situ Chemical Oxidation (ISCO) via Injection

Alternative 3 consists of introducing a chemical oxidant into the subsurface via direct-push technology (DPT) injection borings. Unlike Alternatives 1 and 2, Alternative 3 provides the added flexibility of treating soils in areas of the TTZ not accessible to excavation (e.g., soils beneath the dike wall to the south). The ISCO reagent evaluated for use in the Tank 1010 TTZ is a proprietary non-toxic subsurface releasing compound called CoolOx™. The patented Cool-Ox™ process is an in situ remediation technology that combines controlled chemical oxidation with abiotic chemical reduction. Cool-Ox™ was selected as the reagent because it is effective in addressing the site-specific COCs (primarily benzene) and because the reaction is controllable and does not create heat, eliminating safety concerns related to the high COC concentrations and proximity to nearby sensitive structures.

4.3 Remedial Alternative Evaluation

The alternatives presented in Section 4.2 were evaluated against the following balancing criteria:

- **Long-Term Effectiveness**: Each alternative was evaluated for its effectiveness in both groundwater and soil.
- **Toxicity, Mobility, and Volume Reduction**: This criterion considers the degree to which hazardous substance are treated and reduced.
- **Short-Term Effectiveness**: This criterion considers short-term effectiveness and risks that the remedies impose.
- **Implementability**: This criterion considers the degree of difficulty anticipated in implementing a particular remedy under the technical constraints posed by the site.
- **Cost**: This criterion considers the relative cost range of a remedy, including capital and long-term operations and maintenance (O&M).

Each alternative was considered equally acceptable to the community and state. Relative ratings (low, moderate, and high) are assigned to these criteria, with a rating of high being the most desirable.

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4.4 Comparative Analysis

4.4.1 Alternative 1 – Excavation, Ex Situ Onsite Treatment, and Offsite Disposal or Onsite Reuse

4.4.1.1 Effectiveness

Alternative 1 has a high short-term and long-term effectiveness of reducing benzene mass present within the upper 20 feet of the TTZ. Removal of the shallow source mass will eventually help reduce the VOC concentrations in groundwater. However, the long-term effectiveness could be affected by residual mass remaining in soils not accessible to excavation. This will ultimately result in long-term back diffusion of VOCs to groundwater.

4.4.1.2 Toxicity, Mobility, and Volume Reduction

Alternative 1 is effective at reducing toxicity, mobility, and volume in the TTZ. Removed materials would be treated and the COCs effectively destroyed. However, some source area soils are inaccessible and would remain in place.

4.4.1.3 Implementability

Alternative 1 has a low-to-medium implementability due to the location of the TTZ relative to adjacent structures and the soil conditions. Sheet piling would be required to protect the active railroad lines to the north, Tank 1010 to the south, and utilities and a tunnel to the west. Vibrations created by placement of the sheet piles could damage the older utilities and structures associated with the Tank 1010 impoundment. Additionally, the working space required to excavate, transport, and treat the material onsite is limited. The alternative would create a large flow of construction traffic in a part of the facility with limited accessibility.

Additionally, utility infrastructure would need to be constructed to support onsite treatment operations.

4.4.1.4 Cost

The capital costs to implement Alternative 1 are high. The costs could become more significant if dewatering and onsite pre-treatment of the water are necessary.

4.4.2 Alternative 2 – Excavation, Offsite Treatment, and Offsite Disposal

4.4.2.1 Effectiveness

The effectiveness of Alternative 2 is similar to that of Alternative 1.

4.4.2.2 Toxicity, Mobility, and Volume Reduction

Alternative 2 is effective at reducing toxicity, mobility, and volume in the TTZ. Unlike Alternative 1, removed materials would not be treated and would instead be disposed in an offsite landfill. Some source area soils are inaccessible and would remain in place.

4.4.2.3 Implementability

Unlike Alternative 1, significantly less space is needed for offsite treatment, and utilities do not need to be constructed. However, Alternative 2 still exhibits a low-to-medium implementability due to the need for sheet piling and relatively small working area in which to perform excavation, loading, and transport activities. This alternative would greatly increase the flow of truck traffic through the facility as waste material is transported offsite for treatment and disposal as a hazardous waste.

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4.4.2.4 Cost

The capital costs to implement Alternative 2 are high. The costs could become more significant if dewatering and onsite pre-treatment of the water are necessary.

4.4.3 Alternative 3 – ISCO via Injection

4.4.3.1 Effectiveness

This alternative has a medium-to-high effectiveness degrading dissolved benzene in groundwater, but is less effective in addressing residual, isolated nonaqueous-phase liquid (NAPL). ISCO is generally less effective in treating VOCs entrained in clayey soil such as those present in the Tank 1010 Area TTZ; however, effectiveness may be increased though soil mixing or more closely spaced injection points to improve contact of the oxidants with the VOCs. Effectiveness can also be improved by multiple injections.

4.4.3.2 Toxicity, Mobility, and Volume Reduction

Alternative 3 is effective at reducing toxicity, mobility, and volume in the TTZ where COCs can be contacted by the chemical oxidant. It is considered less effective than excavation due to the presence of clayey soil. Some source area soils are inaccessible and would remain in place.

4.4.3.3 Implementability

This alternative can be easily implemented within the TTZ because the equipment, vendors, and materials are readily available and can be utilized in the relatively small work area necessary to address the TTZ. Some source area soils are inaccessible.

4.4.3.4 Cost

The capital costs are medium-to-high to implement an ISCO remedy, depending on the reagent selected and the unknown number of injection events that may be required to reduce the high source area benzene concentrations to acceptable levels.

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Implementation of the Selected Remedy

Alternative 3, ISCO via injection, was selected as the remedy at the Tank 1010 Area. As stated in Section 4.2.3, the oxidant selected for application consisted of Cool-Ox™, a proprietary reagent developed by Deep Earth Technologies, Inc. (DTI). Between February and August 2014, CH2M worked with DTI to develop a phased approach for implementing Alternative 3. In addition to focusing on the 5- to 20-foot-bgs vertical interval within the TTZ, 20 to 35 feet bgs was also targeted to enhance the effects treatment in the lower portion of the fine-grained unit would eventually have on benzene concentrations in the underlying aquifer.

In October 2014, prior to implementing injection activities, CH2M completed demolition of the two inactive railroad sidings, inactive piping within the concrete pipe trench, and the concrete pipe trench located within the TTZ. An approximate 30-foot section of the concrete trench in the eastern portion of the TTZ was left in place because it contained piping for Tank 1009.

A summary of the phased approach follows:

- Phase 1 (November 2014) – Complete pilot injection of Cool-Ox™ to assess the ability to inject and distribute the reagent within predominantly fine-grained soils of the TTZ. The pilot injection area was approximately 20 square feet (centered over the highest benzene concentration area historically detected within the TTZ and ranged in depth from 5 to 35 feet bgs. Observations made during Phase 1 allowed CH2M and DTI to optimize the injection boring spacing and delivery approach.
- Phase 2 (November and December 2014) – Application of Cool-Ox™ across the remainder of the TTZ (approximately 110-foot by 20-foot area) at depths ranging from 5 to 35 feet bgs. Injection borings were spaced approximately 4 feet apart. The volume of Cool-Ox™ injected ranged between 65 and 85 gallons per injection boring, resulting in a total Phase 1 and Phase 2 volume of approximately 7,300 gallons injected. The injection methods were field adjusted through Phase 2 to optimize the volume of reagent injected and distribution within the subsurface.
- Phase 3 – Post-application soil and groundwater performance monitoring was completed at 1-month, 3-month, and 9-month intervals after injection. Performance monitoring data will be used to determine if additional ISCO applications are required within the entire portion or subset of the TTZ.

Following completion of injection activities, clean gravel borrow material was spread and compacted to raise and slightly level the ground surface for performance monitoring activities.

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SECTION 6

Performance Metrics

The performance metrics for this remedy will be used to reinforce the RAOs (provided in Section 3.1). These metrics include the following:

- Soil samples will be collected following remedy implementation to determine if benzene concentrations and mass in soil have been reduced from levels present prior to injection.
- Groundwater samples will be collected following remedy implementation to evaluate short- and long-term benzene trends in groundwater relative to pore water cleanup levels.

UCC will use the performance metrics to determine whether additional ISCO applications are feasible or another remedial technology needs to be considered. If additional ISCO injection work is completed, UCC will also evaluate whether the size of the TTZ can be optimized to provide focused and aggressive treatment within a limited area or depth interval.

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References

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CH2M. 2013. *HPH and Tank 1010 Pore Water Characterization Report,* Bayer CropScience Institute Facility, Institute, West Virginia. October.

CH2M. 2014. Updated V*apor Intrusion Risk Assessment Report,* Bayer CropScience Institute Facility, Institute, West Virginia. April.

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Table

Table 4-1. Remedial Technology Screening Results
Tank 1010 Area Remedial Approach Report, Institute, West Virginia

Remedial Technology	Process Options	Descriptions	Effectiveness	Implementability	Relative Cost Range	Key Uncertainties	Screening Comment
INSTITUTIONAL AND ENGINEERING CONTROLS							
Administrative/ institutional controls	Deed restrictions/ environmental covenant	Restricts access to contaminated media through environmental covenants on property deeds. Notices to prevent installation of potable wells in area exceeding regulatory thresholds. Establishes construction and land use restrictions.	Low. Effective in protecting human health by establishing restrictions on land development, well installation, and groundwater use. Not effective in reducing source area mass.	High. Requires working with stakeholders at Institute Facility.	Low. Periodic inspection of the use restrictions would be required, thus incurring minimal operation and maintenance (O&M) costs.	Minimal.	Technology retained for further evaluation. Would likely be combined with another technology.
Physical restriction to impacted areas	Fence and/or signs	Restricts access to contaminated media through physical controls.	Low. Not effective in reducing source area mass.	High. Fence and signs can be installed around source areas in soil.	Low. Low maintenance cost related to security, maintenance of fences, worker medical monitoring, etc.	Minimal.	Technology not retained for further evaluation because existing fence and gate prevents unrestricted access to area.
NATURAL ATTENUATION							
Monitored natural attenuation (MNA)	MNA	Monitors volatile organic compound (VOC) concentrations in groundwater by periodic sampling of groundwater beneath the contaminated area.	Soil: Medium. Groundwater: Medium. Natural attenuation is less likely to be effective in high-concentration source areas. Often used after implementation of other active technologies. Residual source concentrations not actively treated will lengthen the timeframe in which the plume stabilizes and shrinks. However, natural attenuation may be effective along the edges of the plume where concentrations are more dilute. Physical, biological, and geochemical conditions must be suitable for attenuation without adjustments to the natural conditions.	High Existing well network in place. Additional wells, if necessary, can be easily installed.	Low. Low O&M costs associated with periodic soil and groundwater sampling.	Minimal.	Technology retained for further evaluation. Would likely be combined with another technology.
IN SITU TREATMENT							
Physical	Extraction wells to pump and treat groundwater within or downgradient of source area	Installation of wells in native soils to extract contaminated groundwater. Groundwater may require treatment before discharge to wastewater treatment works. Groundwater extraction draws down the groundwater level, leaving residuals adsorbed to the soil. After the groundwater level returns to its normal level, VOCs adsorbed to soil can back diffuse into groundwater.	Soil: Not applicable. Groundwater: When installed in native soils: 1) Low to medium in areas where inter-bedded silts and clays are more dominant in saturated zone; 2) Medium in areas where sand and gravel layers are more predominant in saturated zone. Effective in removing potential nonaqueous phase liquid (NAPL). Pumping can provide hydraulic control and may minimize vertical and horizontal migration of constituents of concern (COCs). Does not treat contamination in vadose zone low potential to remove significant mass.	Medium to high. Extraction wells can be installed around the Tank 1010 Area.	High. Capital cost and O&M cost dependent on water treatment requirements. Pump test required to determine capture zone and assess treatment requirements.	Pump test required to assess capture zone. Groundwater chemistry evaluation to develop a treatment process.	Technology not retained for further evaluation. Could be combined with other in situ technologies to enhance groundwater migration from treated areas hydraulically upgradient of Tank 1010 to areas downgradient. However, groundwater migration pathways are not of concern based on recent pore water data. In addition, groundwater extraction does not address shallow source material.

Table 4-1. Remedial Technology Screening Results
Tank 1010 Area Remedial Approach Report, Institute, West Virginia

Remedial Technology	Process Options	Descriptions	Effectiveness	Implementability	Relative Cost Range	Key Uncertainties	Screening Comment
	Vacuum enhanced extraction (multi-phase extraction [MPE])	Combines soil and groundwater treatment for VOCs. Accelerates removal of dissolved-phase groundwater contamination, remediates capillary fringe and smear zone soils, and facilitates removal of vadose zone soil contaminants. Removes NAPL (if present) and related COCs. May require treatment systems for both off-gas and extracted groundwater. Stimulates biodegradation of petroleum constituents in the unsaturated zone by increasing the supply of oxygen, in a manner similar to that of bioventing.	Soil: Low (if not combined with fracturing); medium (if combined with fracturing). Shallow groundwater: Medium (if combined with fracturing). Deep groundwater: Not applicable. Demonstrated to be effective over a wide range of conditions. Increases the effectiveness of vapor extraction by lowering the water table and, therefore, increasing air-phase permeability in the vadose zone and shallow groundwater zone. Can be effective in removing NAPL. Treatment time is reduced by removing soil gases and contaminated groundwater from a common extraction well.	Low to medium. Minimal disturbance to site operations; can be implemented beneath structures. Fracturing of vadose zone may be required to enhance effectiveness in soil and shallow groundwater. However, fracturing may not be able to be implemented in source area. May be difficult to apply where the water table fluctuates unless water table depression pumps are employed.	High capital cost and medium O&M cost. Costs are dependent on the type of process and treatment equipment required to handle and treat process vapor and extracted water.	Pilot test or phased approach may be required to assess effectiveness. Groundwater chemistry evaluation to develop a treatment process for extracted groundwater.	Technology not retained for further evaluation because soil fracturing cannot be implemented within railroad right-of-way (ROW) north of Tank 1010. Source material in ROW comprised of clayey soil and has high degree of saturation in capillary zone above water table.
	Air sparge (AS)/soil vapor extraction (SVE)	AS injects air into the subsurface saturated zone and vents through the unsaturated zone to remove subsurface contaminants. SVE system controls the vapor plume migration by a series of extraction wells. Soil fracturing would be necessary due to the clay soils in the vadose zone. A vacuum is applied to SVE wells to extract/remove vadose zone VOCs through desorbtion and volatilization processes. Off-gas treated prior to release to atmosphere.	Soil: Low (if not combined with fracturing); medium (if combined with fracturing). Groundwater: Low to medium in fine-grained soils. Medium to high in coarse-grained soils. SVE effectiveness limited by presence of partially saturated low-permeability soils and perched groundwater in vadose zone. Effectiveness can be improved by fracturing. AS effectiveness may be limited by presence of inter-bedded clays, silts, and sands within the saturated zone. Air will flow outwards and upwards along preferential pathways, resulting in potential for untreated zones. Benzene concentrations in core of plume may be toxic for biological processes typically associated with AS technology.	Low to medium. Minimal disturbance to site operations; can be implemented beneath structures. Fracturing of vadose zone may be required to enhance effectiveness in soil and shallow groundwater. However, fracturing may not be able to be implemented in source area. May be difficult to apply where the water table fluctuates unless water table depression pumps are employed.	Medium-to-high capital cost and medium O&M cost. Costs are dependent on the type of process and treatment equipment required to handle and treat process vapor and extracted water.	Pilot test or phased approach may be required to better assess effectiveness.	Technology not retained for further evaluation because soil fracturing cannot be implemented within railroad ROW north of Tank 1010. Source material in ROW comprised of clayey soil. AS effectiveness could be limited by heterogeneous soil geology (interbedded sands, silts, clays) and high concentrations.
	Ozone sparging	Ozone is injected into the aquifer to oxidize VOCs in the saturated zone.	Soil: Low. Groundwater: Low in fine-grained soils., Medium to High in coarse-grained soils Effectiveness may be limited by presence of inter-bedded clays, silts, and sands within the saturated zone. Ozone will flow outwards and upwards along preferential pathways, resulting in potential for untreated zones. Potential competition from organic content in the formation (other than VOCs).	Medium. Minimal disturbance to site operations; can be implemented beneath structures. Organic content may require high ozone dosing for longer duration. Ozone generators can pose health and safety (H&S) risks to workers that need to be managed. Additionally, ozone can be corrosive to certain materials from which underground structures or utilities are constructed.	Medium to high capital cost and medium O&M cost. Ozone generation is costly and can be difficult to maintain over longer term. Pilot test or phased approach required.	Pilot test or phased approach required to assess effectiveness. Potential for ineffective distribution of ozone without supplemental fracturing given site hydrogeology.	Technology not retained for further evaluation due to low effectiveness in soils health and safety concerns.

Table 4-1. Remedial Technology Screening Results
Tank 1010 Area Remedial Approach Report, Institute, West Virginia

Remedial Technology	Process Options	Descriptions	Effectiveness	Implementability	Relative Cost Range	Key Uncertainties	Screening Comment
	Soil flushing	Extraction of contaminants from the soil with water or other suitable aqueous solutions that enhance contaminant solubility. Soil flushing can be performed both ex situ and in situ. Ex situ systems require mechanical mixing. For in situ systems, the extraction fluid can be passed through in-place soils using an injection or infiltration process. Contaminants leach out and reach groundwater, which is then extracted and treated. Extraction fluids must be recovered from the underlying aquifer and, when possible, recycled.	Soil: Low. Groundwater: Not applicable. This technology is not applicable for treating contaminants in groundwater.	Low. Low-permeability soils in the vadose zone may make this technology difficult to implement. Reactions of flushing fluids with soil can reduce contaminant mobility. The potential of washing the contaminants beyond the capture zone and the introduction of flushing fluids to the subsurface may concern regulators.	High capital cost. Aboveground separation and treatment costs for recovered fluids can drive the economics of the process.		Technology not retained for further evaluation due to low effectiveness, implementability, and high cost.
Chemical	Delivery of an oxidizing chemical reagent in target area via injection or soil mixing (In Situ Chemical Oxidation [ISCO])	A chemical oxidant, such as permanganate, persulfate, or catalyzed hydrogen peroxide, can be delivered into the subsurface to destroy VOCs in situ. More than one injection event may be required for high-concentration source areas.	Soil: Low to medium (depending on degree of saturation). Groundwater: Low to medium. The specific degree of constituent removal may vary using ISCO. Rebound (an increase in constituent concentrations after an initial decrease) is also common for ISCO systems. However, the technology does have the potential to treat constituent mass in situ and has been widely implemented. Effectiveness may be limited by presence of inter-bedded clays, silts, and sands within the saturated zone and ability to uniformly distribute ISCO substrate within target treatment interval. Distribution may be enhanced by soil fracturing or by conservative spacing of injection locations.	Medium. Implementation of ISCO would require soil mixing within shallow source area soil or injection borings to treat adsorbed phase and dissolved phase contamination. Bench-scale and/or pilot-scale testing to optimize the remedial approach.	Medium to High. Costs could range widely, depending on the size of the area treated and the number of ISCO events implemented.	The optimal oxidant and dose should be identified via bench-scale and/or pilot-scale tests.	Technology retained for further evaluation.
	Stabilization	Contaminants are rendered less mobile, less soluble, chemically inactive, and less toxic by the addition mixed additives and/or reagents. Measurable indicators of successful processing include leachability, chemical stability and permeability. Resultant product or material is suitable for safe land disposal or, in some cases, can remain in place.	Soil: Low. Groundwater: Not applicable. Effective for semivolatile organic compound (SVOC) contaminated soils but not VOC-contaminated soils.	Low. Implementability limited by site structures. Relocation or demolition of abovegrade structures and underground utilities may be required. Needs mechanical mixing.	High capital cost and medium O&M cost. Treatability study is needed prior to implementation to determine the suitable binding material. May include subsequent monitoring to determine effectiveness. May need multiple applications to achieve targeted cleanup levels.		Technology not retained for further evaluation because of low effectiveness and implementability, and high costs.
Biological	Enhanced in situ bioremediation	Enhanced in situ biodegradation may be achieved by injection of oxygen releasing compounds. Injection points would be installed to create treatment zones, where feasible, within the source area.	Soil: Low. Groundwater: Low to medium. Effectiveness may be limited by presence of inter-bedded clays, silts, and sands within the saturated zone to uniformly distribute oxygen releasing compounds within target treatment interval. Limited groundwater flow in inter-bedded or	Low to medium. Minimal disturbance to site operations; can be implemented beneath structures.	High. Costs could range widely, depending on the size of the area treated and the number of injection events implemented. Pilot test and bench test may be required.	Pilot and bench tests may be required to assess effectiveness.	Technology not retained for further evaluation due to low to medium effectiveness and implementability, and high cost. Other preferable remedial technologies are available to add oxygen to the subsurface.

Table 4-1. Remedial Technology Screening Results

Tank 1010 Area Remedial Approach Report, Institute, West Virginia

Remedial Technology	Process Options	Descriptions	Effectiveness	Implementability	Relative Cost Range	Key Uncertainties	Screening Comment
			confined zones may limit effectiveness of biodegradation processes. Treatability testing would be required to identify suitable conditions to promote biodegradation and whether degrading bacteria are naturally present. Effectiveness may be limited in core source areas where benzene concentrations are high enough to be toxic to microorganisms.				
	Biosparge (AS/B)	AS/B is similar to AS, only the rate of sparging is reduced to promote aerobic biodegradation of VOCs rather than stripping at a higher flow rate.	Soil: Low. Groundwater: Low to medium for deeper groundwater. Effectiveness may be limited by presence of inter-bedded clays, silts, and sands within the saturated zone. Air will flow outwards and upwards along preferential pathways, resulting in aerobic and anaerobic micro-zones within the overall target treatment zone. Effectiveness may be limited in source areas where benzene concentrations are high enough to be toxic to microorganisms.	Medium. Minimal disturbance to site operations; can be implemented beneath structures.	Low to medium capital cost and low to medium O&M cost. Pilot test or phased approach may be required.	Pilot test or phased approach may be required to assess effectiveness. Not expected to significantly remove/reduce mass in the highest concentrated areas of the site.	Technology not retained for further evaluation due to low effectiveness in soil and high source area concentrations in groundwater.
	Pure oxygen sparging	Pure oxygen is injected into the aquifer to deliver high concentrations of oxygen to enhance biological processes in the saturated zone.	Soil: Low. Groundwater: Low to medium. Effectiveness may be limited by presence of inter-bedded clays, silts, and sands within the saturated zone. Oxygen will flow outwards and upwards along preferential pathways, resulting in untreated zones. Potential competition from organic content in the formation (other than COCs). Effectiveness may be limited in source areas where concentrations of benzene are high enough to be toxic to microorganisms.	Medium. Minimal disturbance to site operations; can be implemented beneath structures. H&S risks associated with generating/ handling pure oxygen.	Medium to high capital cost and medium O&M cost. Pilot test or phased approach may be required.	Pilot test or phased approach may be required to assess effectiveness. Not expected to significantly remove/reduce mass in the highest concentrated areas of the site. Not expected to achieve sufficient distribution in shallow zone without supplemental fracturing	Technology not retained for further evaluation due to low effectiveness in soils.
Thermal technology	Thermal conductive heating (TCH)	TCH is an in situ conductive thermal process used to heat the target zone to remove VOCs from soil and groundwater. A heater element is installed across the target heating zone. From the heater element, radiant heat is transferred to the well casing, and from the steel well casing heat is subsequently transferred to the surrounding subsurface materials. SVE and groundwater extraction are implemented as part of this process. SVE promotes air flow through the heated zone	Soil: High. Groundwater: High. TCH works in tight soils, clay layers, and soils with wide heterogeneity in permeability or moisture content that are impacted by a broad range of volatile contaminants. The conductive heating process is uniform in its vertical and horizontal sweep. At high temperatures, contaminant transport can be enhanced by the shrinking and cracking (desiccation) of soil near the heater wells.	Low. Implementability will be limited due to existing site structures. Underground structures must be able to withstand the high temperatures created with thermal heating of the subsurface. Relocation or demolition of abovegrade structures and underground utilities may be required. Treatment efficiency is directly related to the ability to install heater wells on tight spacing. Inability to treat significant part	High. Depends on energy use and length of time. Typically, thermal technologies are implemented quickly and result in decreased O&M duration. Production of off-gas would require a SVE system with vapor treatment equipment. Although the capital cost for TCH may be higher than other technologies, when life cycle costs of all options are	Relocation of aboveground structures and underground utilities currently not an option. Partial implementation of this technology would not achieve the benefits of thorough source treatment and high mass removal typically associated with thermal technologies.	Technology not retained for further evaluation due to low implementability because of infrastructure, including railroad, utility corridor, and ASTs.

Table 4-1. Remedial Technology Screening Results

Tank 1010 Area Remedial Approach Report, Institute, West Virginia

Remedial Technology	Process Options	Descriptions	Effectiveness	Implementability	Relative Cost Range	Key Uncertainties	Screening Comment
		and captures VOCs volatilized in the vadose zone. Groundwater is pumped through extraction wells to promote groundwater flow through the heated zone.	Preferential flow paths are created even in tight silt and clay layers, allowing flow and capture of the vaporized contaminants. TCH can be augmented with steam-enhanced extraction for sites with some higher-conductivity zones. In the post-treatment stage, enhanced microbial degradation has been observed at sites where thermal treatment has been implemented.	of mass would reduce the cost to mass removal benefit associated with TCH.	considered, and the associated saving of multiple years of O&M, TCH may result in a lower total cost for remediation than other more O&M intensive approaches.		
	Steam enhanced extraction (SEE)	SEE achieves onsite separation and treatment of VOCs through steam injection through wells and extraction of hot fluids. The injected steam is used to heat the subsurface to target treatment temperatures, typically the boiling point of the VOCs. Additionally, vaporized contaminants rise to the vadose zone where they can be captured by an SVE system.	Soil: Low. Groundwater: Low to medium. SEE is effective for large and deep sites with significant groundwater flow within permeable soils. The SEE technology allows for high extraction of fluids and displaces large amounts of groundwater towards the extraction wells. As a result, less water needs to be heated to achieve target temperatures within the aquifer. Displacement also facilitates hydraulic control of NAPL mobility. The steam sweep through the aquifer and accompanying pressure gradient displaces the mobile NAPL and vaporized components as an oil front, which is recovered at the extraction wells.	Low. Implementability will be limited in some areas due to existing site structures. Relocation or demolition of abovegrade structures and underground utilities may be required. Partial implementation across the site would limit effectiveness.	High. Energy use to strip VOCs in groundwater would be less in more permeable soils. Tank 1010 site characterized by interbedded fine and coarse grain deposits, thus resulting in increased energy costs to remediate groundwater via SEE alone.	Relocation of aboveground structures and underground utilities currently not an option. Partial implementation of this technology would not achieve the benefits of thorough source treatment and high mass removal typically associated with thermal technologies.	Technology not retained for further evaluation due to low effectiveness in the interbedded soils at the Tank 1010 site, and due to low implementability because of infrastructure.
	Electrical resistance heating	An electric current is used to heat less permeable soils, such as clays and fine-grained sediments, which causes low-boiling-point VOCs to volatilize. Electrical resistance heating does not attain temperatures as high as thermal conductive heating (maximum temperature = boiling point of water). SVE and groundwater extraction are implemented as part of this process. SVE promotes air flow through the heated zone and captures VOCs volatilized in the vadose zone. Groundwater is pumped through extraction wells to promote groundwater flow through the heated zone.	Soil: Medium. Groundwater: Medium. Effective for treating VOCs in low-permeability soils in the perched water, vadose zone, capillary fringe, and saturated zones.	Low. Implementability will be limited in some areas due to existing site structures. Underground structures must be able to withstand the high temperatures created with thermal heating of the subsurface. Relocation or demolition of abovegrade structures and underground utilities may be required. Treatment efficiency is directly related to the ability to install electrical probes on tight spacing. Inability to treat significant part of mass would reduce the cost to mass removal benefit associated with TCH. Site restrictions (Class I Div II) may limit/ restrict use of the technology.	High. Depends on energy use and length of time. Typically, thermal technologies are implemented quickly and result in decreased O&M duration. Production of off-gas would require a SVE system with vapor treatment equipment. Although the capital cost for TCH may be higher than other technologies, when life cycle costs of all options are considered, and the associated saving of multiple years of O&M, TCH may result in a lower total cost for remediation than other more O&M-intensive approaches.	Relocation of aboveground structures and underground utilities currently not an option. Partial implementation of this technology would not achieve the benefits of thorough source treatment and high mass removal typically associated with thermal technologies.	Technology not retained for further evaluation because of inter-bedded nature of soil strata at the Tank 1010 area and due to low implementability because of infrastructure.

Table 4-1. Remedial Technology Screening Results

Tank 1010 Area Remedial Approach Report, Institute, West Virginia

Remedial Technology	Process Options	Descriptions	Effectiveness	Implementability	Relative Cost Range	Key Uncertainties	Screening Comment
REMOVAL							
Excavation and offsite disposal	Excavation and offsite disposal to RCRA Subtitle C or Subtitle D landfill	Remove material for disposal in permitted landfill.	Medium to high. Removal of shallow source area material will eventually reduce the VOC concentrations in groundwater. Residual mass remaining within soils inaccessible to excavation will result in long-term back diffusion of VOCs to groundwater.	Low to Medium. Shallow source area excavation possible upgradient of Tank 1010 and within secondary source area. Sheet piling will be required to stabilize excavation and prevent damage to adjacent structures. Soils become saturated at approximately 10 feet bgs.	High. Capital costs for excavation, dewatering, and treatment/disposal significant. Disposal to landfill will be dependent on satisfying land disposal requirements. Pretreatment of soil prior to offsite disposal may be necessary.	Ability to install sheet pile adjacent to active railroad and ASTs to adequately protect excavation; Potential for damage to adjacent structures. Regulations will need to be further assessed to determine whether there are waste disposal restrictions or pre-treatment of soil is required prior to offsite transport and disposal.	Technology retained for further evaluation for source area soil.
	Excavation and stabilization before offsite disposal	Immobilizes contaminants and disposes treated wastes offsite as non-hazardous waste.	Low. Effective for SVOC but not VOC-contaminated soils.	Low. Would require significant excavations that cannot be practically excavated given the site use and presence of existing structures.	High.		Technology not retained for further evaluation because of low effectiveness and implementability, and high cost.
	Excavation, treatment, and offsite disposal or onsite reuse	Removes impacted soils, treat onsite to achieve targeted cleanup levels, and either dispose at a permitted landfill or reuse onsite.	Medium to High. Removal of shallow source area material will eventually reduce the VOC concentrations in groundwater. Residual mass remaining within soils inaccessible to excavation will result in long-term back diffusion of VOCs to groundwater.	Low, Shallow source area excavation possible upgradient of Tank 1010 and within secondary source area. Sheet piling will be required to stabilize excavation and prevent damage to adjacent structures. Soils become saturated at approximately 10 feet bgs.	High. Capital costs for excavation, dewatering, onsite treatment, and potential offsite disposal significant. Disposal to landfill versus on site reuse will be dependent on level to which benzene concentrations in soil can be treated onsite.	Ability to install sheet pile adjacent to active railroad and ASTs to adequately protect excavation; potential for damage to adjacent structures. Uncertain the degree to which benzene concentrations could be reduced (decision driver for offsite disposal at Subtitle C or D facility versus onsite reuse)	Technology retained for further evaluation for source area soil.

Note: Gray shading indicates "Technology NOT retained for further evaluation."

Figures

Figure 1-1
Institute Facility Overview and Site Location Map
Tank 1010 Area Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

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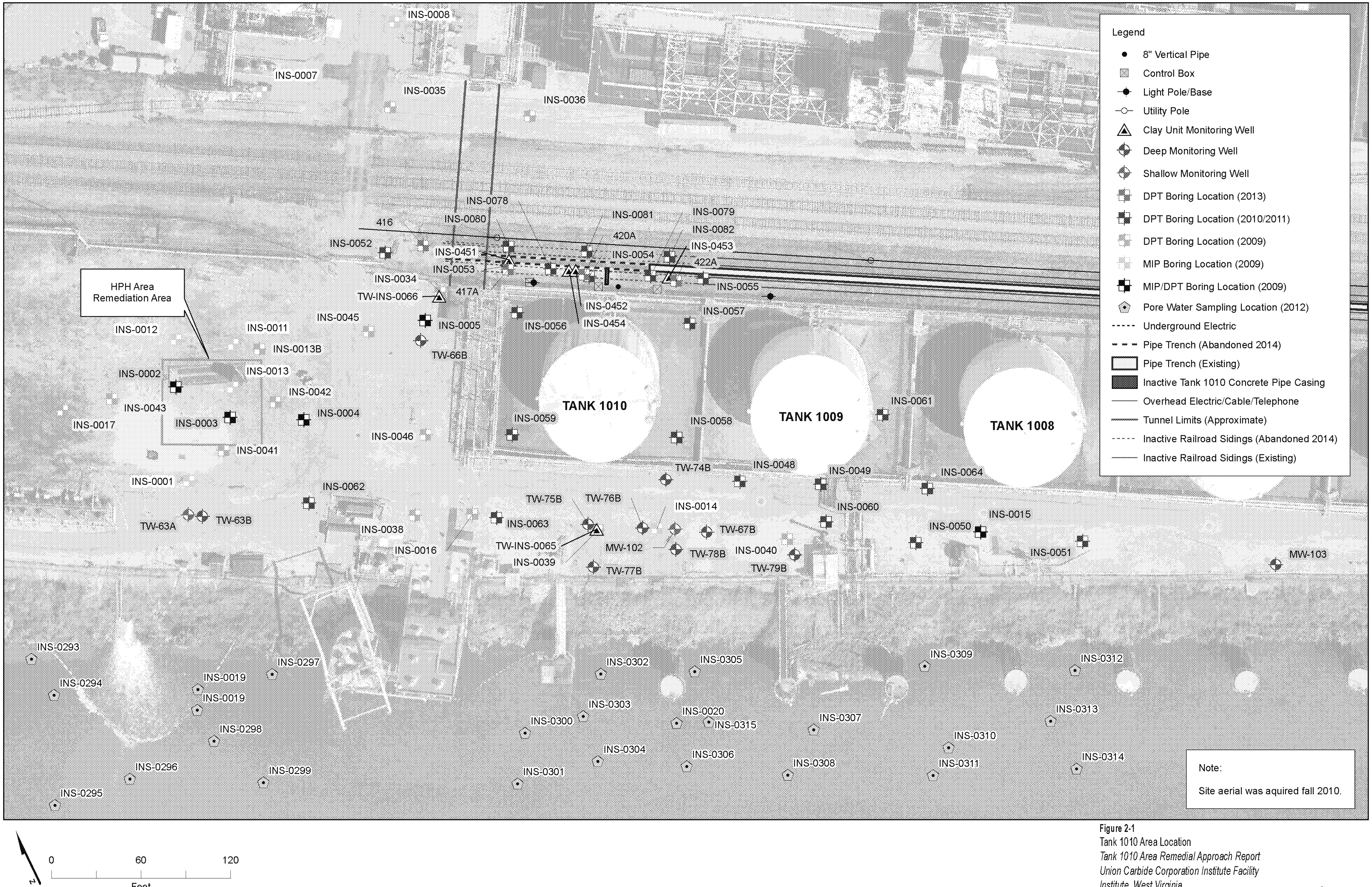

Figure 2-1
Tank 1010 Area Location
Tank 1010 Area Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

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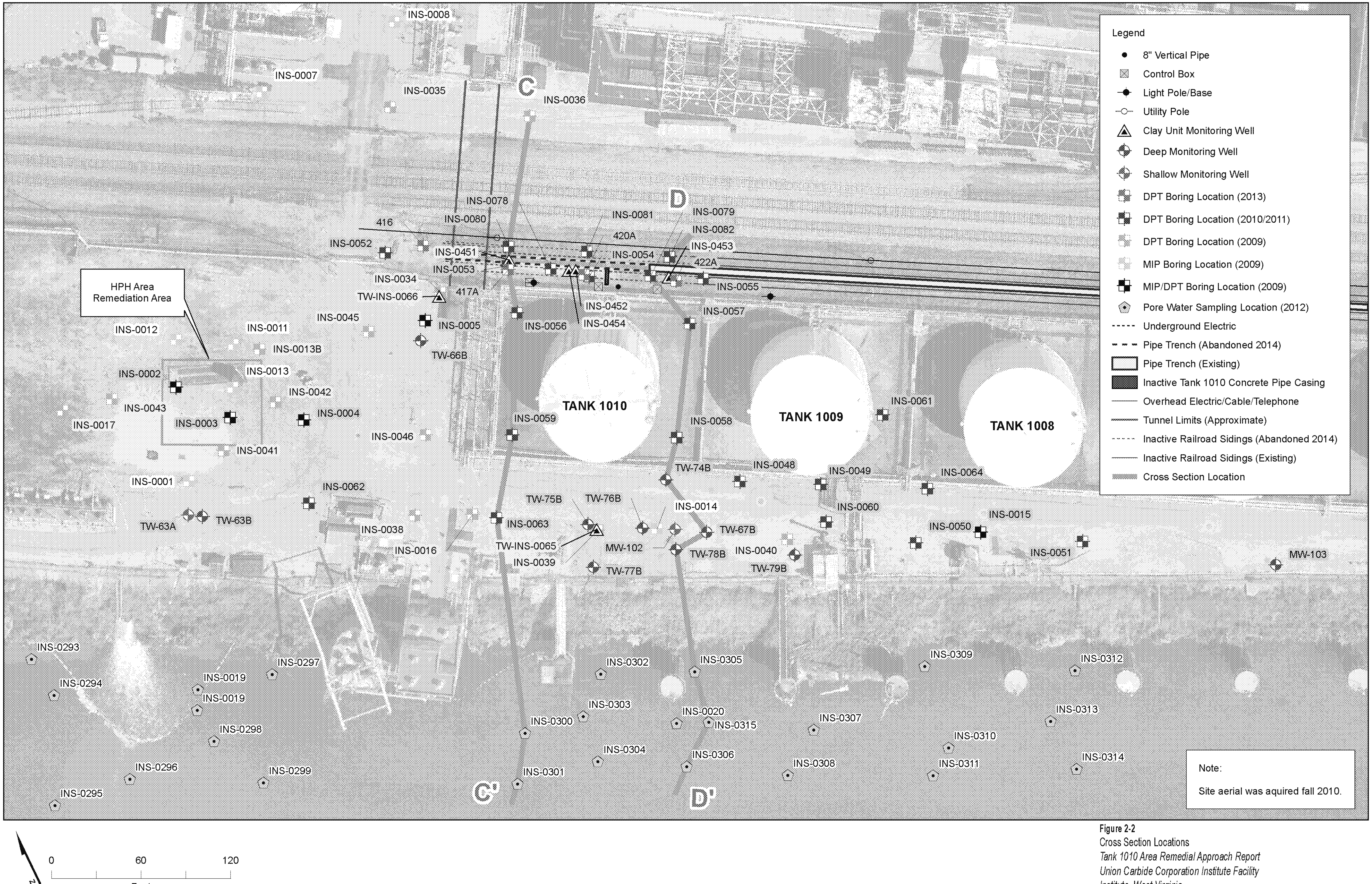

Figure 2-2
Cross Section Locations
Tank 1010 Area Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

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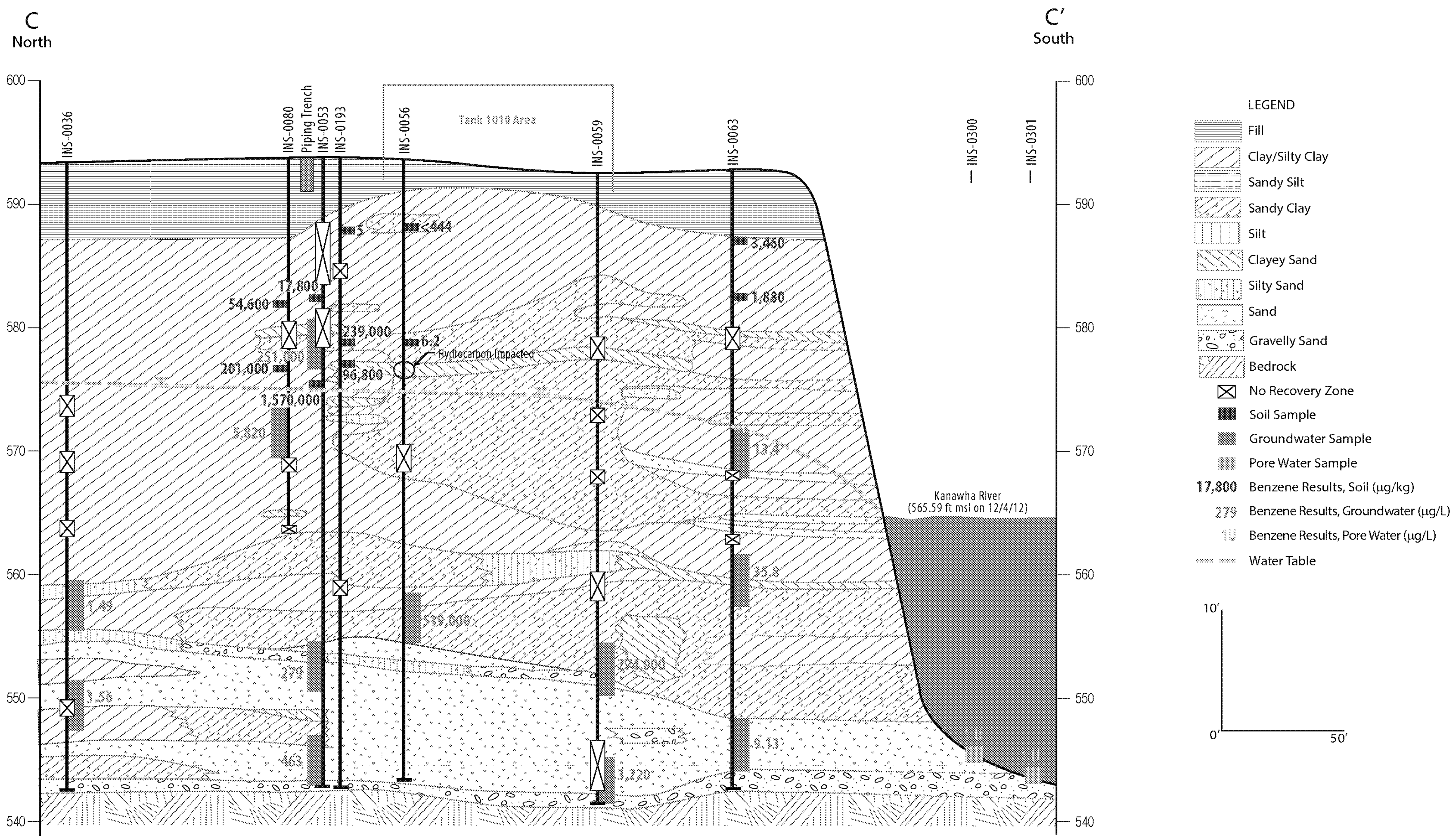

FIGURE 2-3
Geologic Cross Section C-C' – Benzene
Tank 1010 Remedial Approach Report
Union Carbide Corporation Institute
Institute, West Virginia

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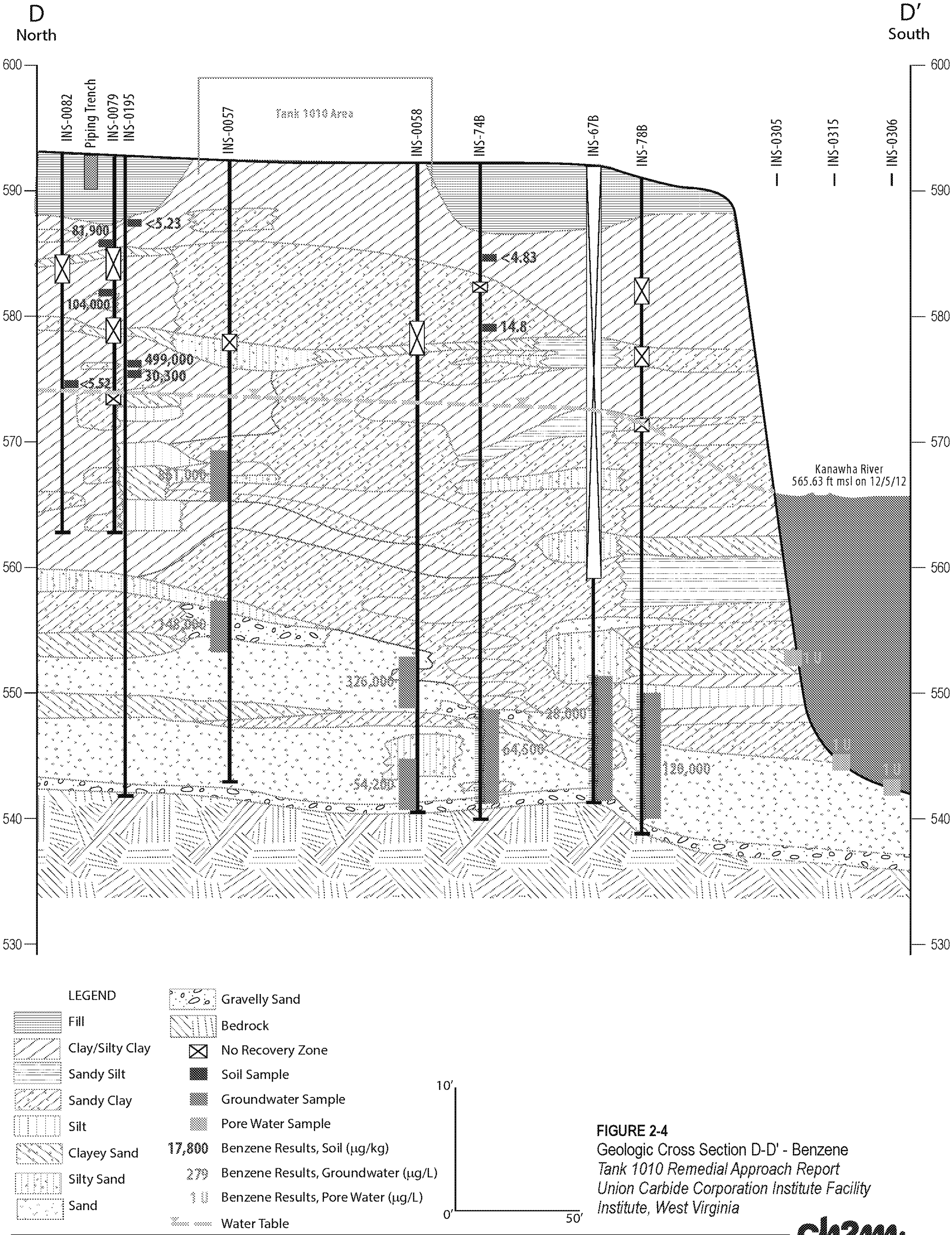

FIGURE 2-4
Geologic Cross Section D-D' - Benzene
Tank 1010 Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

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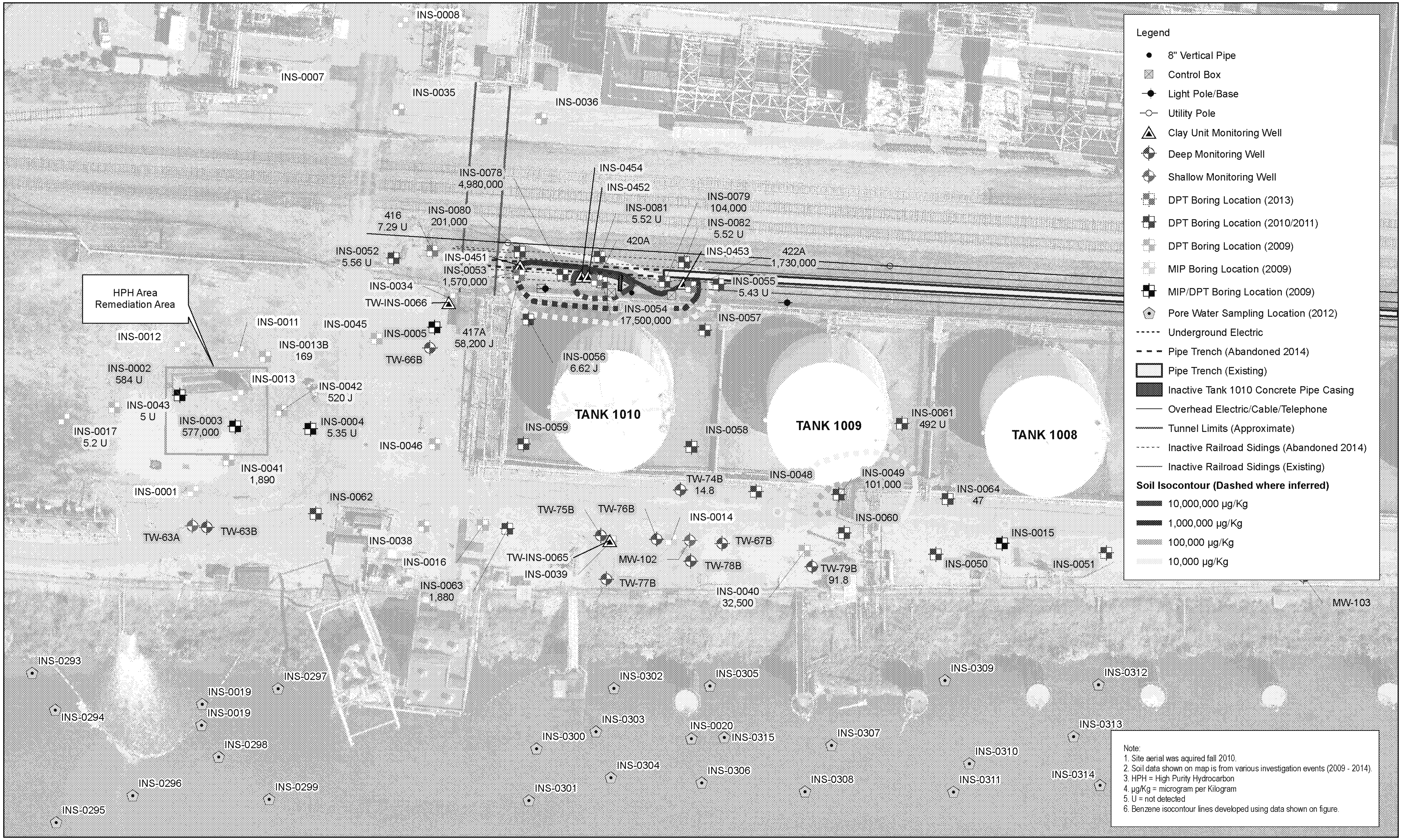

Figure 2-5
Benzene in Soil
Tank 1010 Area Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

MKE \\LAKEFRONT\PROJ\GIS\DOW\INSTITUTE\REPORTS\2015\TANK1010AREAREMEDIALAPPROACHREPORT\MAPFILES\FIGURE2_5_BENZENE_IN_SOIL.MXD AMARTI42 11/13/2015 3:00:08 PM

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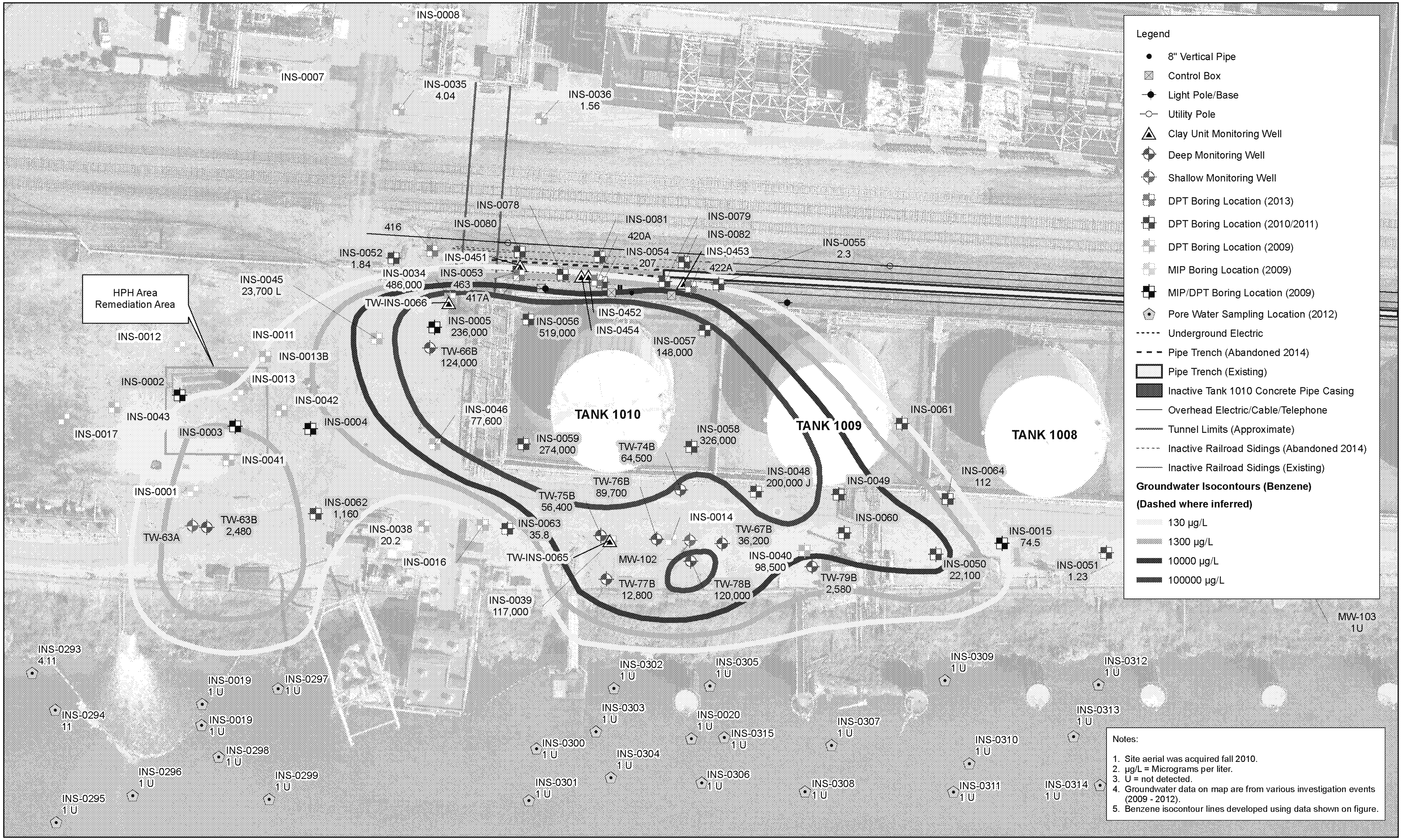

Figure 2-6
Benzene in Groundwater - Aquifer
Tank 1010 Area Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

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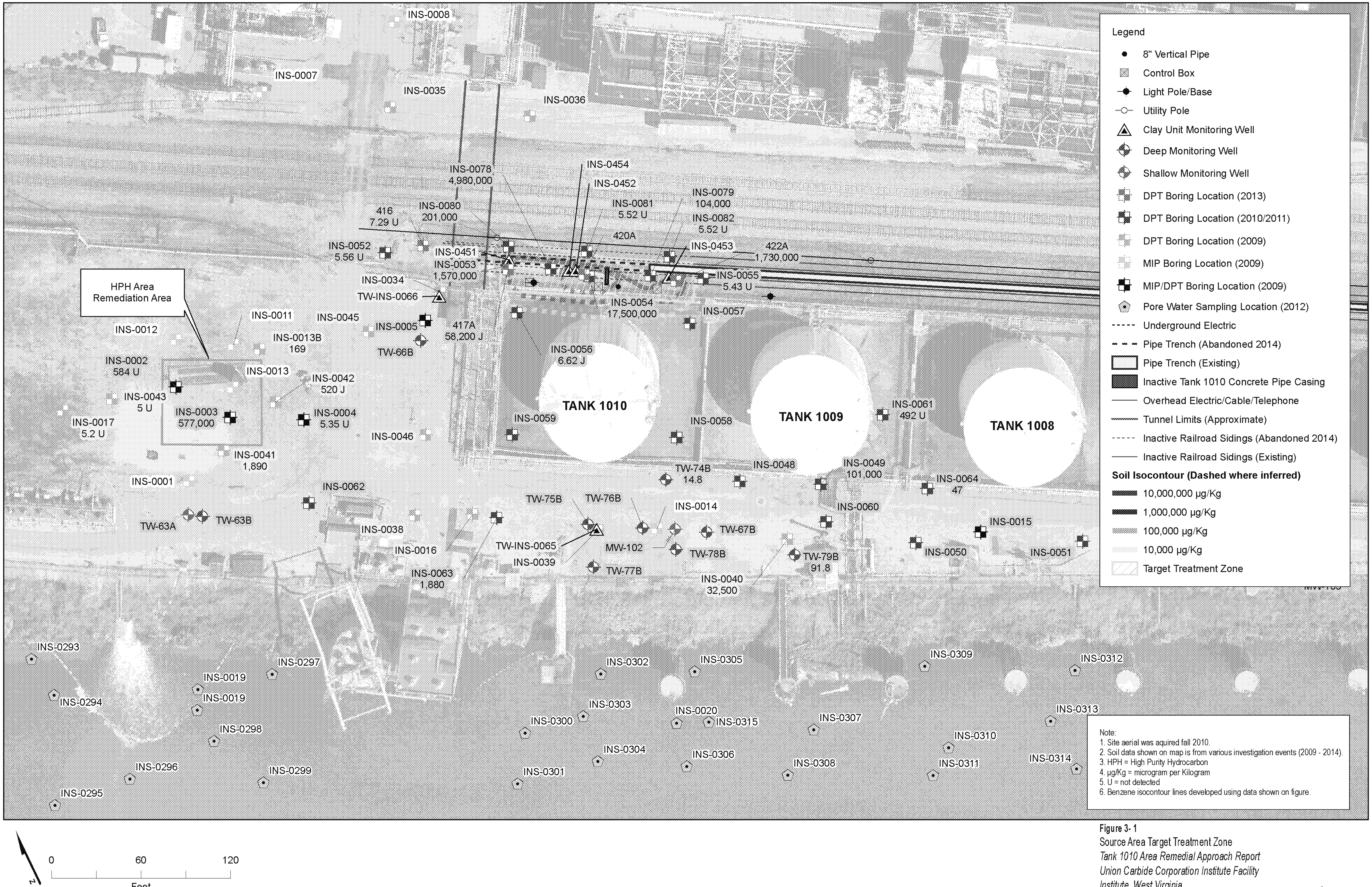

Figure 3-1
Source Area Target Treatment Zone
Tank 1010 Area Remedial Approach Report
Union Carbide Corporation Institute Facility
Institute, West Virginia

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